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Feeding ecology of various age-classes of brown trout in River Nera, Central Italy

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ABSTRACT. We studied the composition of the stomach contents of brown trout (*Salmo trutta trutta*) of different ages in the river Nera, Central Italy. Each age class of fish consumed significantly different prey taxa. Plecopteran nymphs tended to increase in percentage as the individuals became older, while ephemeropteran nymphs were always present in high percentage. Trichopteran larvae were the most abundant prey in trout younger than 2+, while their percentage decreased considerably in older fish. The remaining aquatic prey (except dipteran larvae) were scarce and, finally, terrestrial prey were consumed more by older individuals. Vanderploeg & Scavia's index shows a high preference for species of Trichoptera by trout younger than 3+, plecopteran species by those older than three years, and a general negative preference for species of Ephemeroptera by all age classes.

KEY WORDS : *Salmo trutta trutta*, diet, age, Italy.

INTRODUCTION

Salmonids are generally considered as opportunists (Hunt & Jones, 1972) or generalists (Hynes, 1970) since they are unselective on prey. However, the predatory activity of the brown trout (*Salmo trutta trutta* L., 1758) cannot be considered simply proportional to the environmental density of the prey, as shown by Ware (1972) for rainbow trout.

Fochetti et al. (2003) studied the stomach contents of brown trout from the Nera River (Central Italy), confirming the presence of selectivity in its feeding behaviour. In fact, the electivity index showed a negative selection for some species of Ephemeroptera and Diptera and positive selection for species of Trichoptera. Moreover, it was also found that ephemeropteran species dominated spring and summer diets, while trichopteran species prevailed in winter.

Since the diet of fish often changes with body size (Elliott, 1967; Werner & Gilliam, 1984), and in salmonids older fish shift their preferences towards larger prey (Keeley & Grant, 1997), the aim of the present study was to analyse the possible changes in diet between the different age classes of individuals of brown trout in a river of Central Italy. Moreover, we wanted to verify the relationship between the availability of potential macrobenthic prey and their actual presence in the diet, and to compare the electivity values shown by brown trout of different ages.

MATERIALS AND METHODS

The study site was located along the River Nera. This river originates in the Sibilline Mountains (Central Italy) and flows for about 125km, before joining the River Tiber. The study area encompassed the middle 30km region of the river, a river stretch that has been declared Regional Park with the aim of protecting the fish community, which is mainly composed of brown trout, Italian roach (*Rutilus rubilio* Bonaparte, 1837), soufie (*Leuciscus souffia* Risso, 1826), chub (*Leuciscus cephalus* L., 1758) and bullhead (*Cottus gobio* L., 1758) (Mearelli et al., 1996). The trout population is sustained by yearly reintroduction of fry and juveniles. In the study stretch the river has an average width of 6 meters, a depth of 80-90cm, and substratum is mainly composed of cobbles, pebbles and gravel. The river banks are flanked by willow (*Salix* spp.), alder (*Alnus glutinosa* L., 1758), elm (*Ulmus minor*, Miller 1768) and poplar (*Populus nigra* L., 1758) trees.

Macrobenthos was sampled by kicking method (3 minutes searching in all major microhabitats; mesh 0.47mm; see Hellawell, 1978) seasonally, from October 1996 to January 1998, at four sampling sites.

Brown trout were caught by angling along the same stretch where macrobenthos was collected. A preliminary electrofishing was unsuccessful, due to the river's depth, velocity, and bottom irregularities that prevented netting the fish. While angling is a selective method of collecting trout, the feeding habit of angled fish is generally considered to be representative of the feeding habits of the entire population for the size classes represented (Elliott & Jenkins, 1972; Hunt & Jones, 1972; Tippets & Moyle, 1978; Mathooko, 1996). The captures occurred at dawn and before dusk, from February to October 1997, excluding the breeding period in autumn.

A total of 56 trout were caught. After capture, standard length (SL) and total length (TL) of each fish were measured, and a scale sample (6-10 scales) was removed for age determination on the basis of Needham's criteria (1969) with the aid of a stereoscopic microscope. Because brown trout under 13cm are protected, all small individuals were released. Hence, the study included adult fish aged 2 years and older. Stomachs were removed in the field and placed in 10% formalin solution. For each stomach both a qualitative and a quantitative evaluation of the contribution given to the trout's diet from every food item was made. The percentage in the gut content of each prey type for each age class of trout was calculated (%P=number of items of a prey type * 100/total number of items consumed).

VANDERPLOG & SCAVIA's (1979a; 1979b) electivity index was used to quantify prey selection. The index is defined as follows:

$$E = \frac{[W_i - (1/n)]}{[W_i + (1/n)]}$$

where W_i is CHESSON's (1978) coefficient:

$$W_i = \frac{(r_i/p_i)}{\Sigma(r_i/p_i)}$$

n is the number of different categories, r_i is the relative proportion in the diet of a food category and p_i is the proportion of the same category in the benthic community.

This index is used in most fish prey selection studies because it is relatively unbiased. The index can vary from –1 (greatest negative selection) to +1 (greatest positive selection). E gives a good estimate of the effort exerted by the predator in selecting a prey and gives high weight to the prey that, being rare in the environment, requires greater effort from the predator.

A non-parametric observed *versus* expected χ^2-test was employed to detect significant differences in the diet composition between age classes.

RESULTS

Stomachs were full in 51 out of 56 trout investigated; they contained 64 taxa of benthic or terrestrial macroinvertebrates and/or vegetation, which were grouped into 16 categories (Table 1). Aquatic insects were the most ingested prey, particularly trichopteran larvae and ephemeropteran nymphs, while non-insect aquatic animals were rarely eaten by the trout.

The percentage of plecopteran nymphs tended to increase with the individual's age; ephemeropteran nymphs were always present in high percentage (Table 2). Trichoptera larvae formed a high percentage (approximately 50%) in trout three and younger than three years old and after that age the percentage decreased considerably. The remaining aquatic prey (Crustacea, Gasteropoda, Nematoda and Annelida) were not abundant, and terrestrial prey (including adults of Plecoptera, Ephemeroptera and Trichoptera and other arthropods of terrestrial origin) were consumed more by older individuals. Ephemeropteran nymphs and trichopteran larvae were the most abundant prey and were always present in gut contents of trout in age classes 2 and 2+, trichopteran and dipteran larvae in age class 3, ephemeropteran nymphs in age class 3+, ephemeropteran nymphs, followed by dipteran larvae, terrestrial prey and plecopteran nymphs, in age class 4-5.

Differences in diet composition among different age classes were significant between every age class (χ^2 test is not significant only between individuals of age classes 2 and 2+) (Table 3).

If we consider only the aquatic prey (Tables 4 & 5), we obtain the same pattern described in Tables 2 and 3. The most abundant macrobenthic taxon was Ephemeroptera, followed by Diptera; they were generally present in a higher percentage in the macrobenthos than they were in the diet of any age class. Trichopteran species showed opposite tendency.

Vanderploeg & Scavia's index "E" (Table 6) shows high preference for trichopteran prey in trout younger than four, for plecopteran prey in trout older than three, and a general negative preference for ephemeropteran species as prey in all age classes.

TABLE 1

Gut content composition of brown trout showing the number of items found by age classes. n=number of individuals studied in each age class, A=adult, N=nymph, L=larva, Plecop=Plecoptera, Ephem=Ephemeroptera, Trichop=Trichoptera, Dipt=Diptera, Coleop=Coleoptera, Crust=Crustacea, Gast=Gastropoda, Nem=Nematoda, Annel=Annelida, Terr=other terrestrial prey, Veg=vegetation.

Age class	n	Plecop		Ephem		Trichop		Dipt		Coleop		Crust	Gast	Nem	Annel	Terr	Veg	Total
		A	N	A	N	A	L	A	L	A	L							
2	18	0	18	13	102	2	231	0	19	3	0	2	1	1	1	28	18	439
2+	11	0	5	5	89	1	112	0	20	0	3	2	0	0	0	5	23	265
3	10	0	14	2	26	0	119	0	51	0	0	3	0	0	1	1	37	254
3+	5	4	6	0	43	0	12	0	3	1	0	1	0	0	0	6	3	79
4-5	7	3	22	6	72	0	7	0	31	0	0	3	0	0	2	24	4	174

TABLE 2

Percentage in the gut content of each prey type (%P). For each age class of trout, %P =number of items of a prey type * 100/total number of items consumed. Vegetation was not included. Abbreviations as in Table 1.

Age class	n	Plecop		Ephem		Trichop		Dipt		Coleop		Crust	Gast	Nem	Annel	Terr
		A	N	A	N	A	L	A	L	A	L					
2	18	0	4.3	3.1	24.2	0.5	54.9	0	4.5	0.7	0	0.5	0.2	0.2	0.2	6.7
2+	11	0	2.1	2.1	36.8	0.4	46.3	0	8.3	0	1.2	0.8	0	0	0	2.1
3	10	0	6.5	0.9	12	0	54.8	0	23.3	0	0	1.4	0	0	0.5	0.5
3+	5	5.3	7.9	0	56.6	0	15.8	0	3.9	1.3	0	1.3	0	0	0	7.9
4-5	7	1.8	12.9	3.5	42.4	0	4.1	0	18.2	0	0	1.8	0	0	1.2	14.1

TABLE 3

Comparison of gut content of different age classes of brown trout with non-parametric $\chi2$-test (df=14). In bold and italic when p>0.05.

	2+	3	3+	4-5
2	***21.85***	111.33	113.29	660.78
2+		72.68	86.08	463.85
3			241.70	670.70
3+				65.69

TABLE 4

Relative percentage (%) of aquatic macroinvertebrate in the gut content (aquatic components only) and in macrobenthos. Abbreviations as in Table 1 except Others=Gastropoda + Nematoda + Annelida.

Age class	Plecop N	Efem N	Trichop L	Dipt L	Coleop L+A	Crust	Others
2	4.8	27	61.1	5	0.8	0.5	0.8
2+	2.2	38.5	48.5	8.7	1.3	0.9	0
3	6.5	12.1	55.6	23.8	0	1.4	0.5
3+	9.1	65.2	18.2	4.5	1.5	1.5	0
4-5	16.1	52.6	5.1	22.6	0	2.2	1.5
Macrobentos	3.9	60.8	5.9	15.7	4.9	7.8	1.0

TABLE 5

Comparison of gut content (considering only the aquatic preys) of different age classes of brown trout with non-parametric $\chi2$-test (df=6). In bold and italic when p>0.05.

	2+	3	3+	4-5
2	***11.72***	34.95	126.58	650.64
2+		71.61	70.80	395.92
3			205.13	537.98
3+				55.93

TABLE 6

VANDERPLOG AND SCAVIA's (1979a; 1979b) electivity index (E) for the eaten macrobenthic prey. n=number of individuals studied in each age class, A=adult, L=larva, Plecop=Plecoptera, Ephem=Ephemeroptera, Trichop=Trichoptera, Dipt=Diptera, Coleop=Coleoptera, Crust=Crustacea, Others=Gastropoda + Nematoda + Annelida.

Age class	n	Plecop (N)	Efem (N)	Trichop (L)	Dipt (L)	Coleop (L+A)	Crust	Others
2	18	-0.21	-0.65	0.69	-0.75	-0.87	-1	-0.40
2+	11	-0.47	-0.40	0.70	-0.47	-0.64	-0.87	- 1
3	10	- 0.08	- 0.87	0.67	- 0.12	- 1	-0.87	- 0.72
3+	5	0.39	- 0.07	0.50	- 0.55	-0.55	-0.65	- 1
4+5	7	0.52	-0.17	-0.22	0.07	- 1	-0.65	0.10

DISCUSSION

It is usually accepted that the salmonid diet changes with age (ELLIOTT, 1967). Some authors have not detected those differences in diet when trout are two years old or older (i.e. VOLLESTAD & ANDERSEN, 1985). Our results showed that, in fish older than two years, stomach contents differed significantly between the different age classes.

The changes in diet shown by our study cannot be explained by the fact that, in salmonid, prey size is known to change with body size [larger (and older) fish shift their preferences towards larger prey (KEELEY & GRANT, 1997)]. The relationship between prey size and body size has been established in salmonids smaller than 14.5cm (KEELEY & GRANT, 1997), which may simply have difficulties ingesting large macroinvertebrates. In our study all fish were longer than 13cm; moreover, they fed on prey that were smaller than the size predicted by BANNON & RINGLER's (1986) and WANKOWSKY's (1979) foraging model for salmonids. This was also noted by STEINGRÍMSSON & GÍSLASON (2002) for *S. trutta* in Iceland. Nevertheless, the presence of limitations to ingestion of large prey by smaller fish could explain, in our results, the increase of plecopteran nymphs in the diet of older trout (particularly Plecoptera of the genera *Dinocras* and *Perla,* which can reach a length of 3-3.5cm), and the positive values of the electivity index recorded for this prey in trout older than three years.

Fochetti et al. (2003) stressed that trout show a positive selection towards trichopteran prey in the River Nera. Our detailed analysis of gut contents in each age class, even though based on the observation of reduced number of specimens, showed that this is only true for fish younger than four years. The choice of feeding mainly on trichopteran prey was explained by Fochetti et al. (2003) by the reduced mobility of brown trout in winter and by its habit of concealing itself in macrophyte beds in that season. In fact, the brown trout is a visual forager; it shifts to prey on the more available, sedentary trichopteran species in winter, when invertebrate drift is reduced. This shifting in habitat preferences and foraging strategies could be a more common habit in young brown trout than in more experienced and stronger older ones. The same explanation could account for the higher percentage of terrestrial prey in older trout found in our study. The preference for terrestrial prey by older trout has previously been reported for the same species by Neveu & Thibault (1977) in the Pyrenees and Montori et al. (2006) in the Prepyrenees.

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